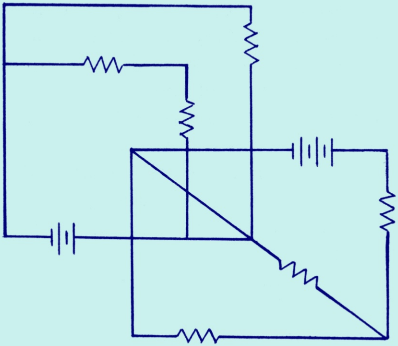
THINGS of science



ELECTRICITY

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ELECTRICITY

Electricity is so much a part of our lives, we do not usually give it much thought nor realize how dependent we are upon it for convenience, entertainment and services until a power failure stops its flow into our homes, hospitals and other buildings. Lamps, television sets, hospital equipment, computers, all the various electrically operated devices suddenly cease functioning, creating a temporary emergency, showing us how much we rely on electric energy and how important it is in the world of today.

What is electricity and how is it produced? How does it work for us?

The experiments in this unit will help answer these questions and provide you with some insight into the basic principles of electricity.

First examine your materials.

INSULATED COPPER WIRE—Wire covered with polyvinyl and nylon jacket; the copper wire inside is coated with tin so is silvery in color; six feet long.

BARE COPPER WIRE—Reddish wire.

GALVANIZED STEEL WIRE—Silver-colored wire about the same diameter as the copper wire.

FINE STEEL WIRE—Fine threadlike stiff wire.

ZINC RIBBON—Silvery ribbon one-eighth inch wide.

ALUMINUM FOIL—Stiff foil; 1½ x 3 inches.

STEEL NAIL

STIFF WHITE PAPER

COMPASS

PLASTIC BAG

Cut your insulated wire into the following lengths: two pieces 10 inches long; two pieces 4 inches long; two pieces 6½ inches long; two pieces 3 inches long; one piece 24 inches long.

Carefully remove about one-half inch of the insulation from the ends of each of the wire pieces to expose the wire.

To do the experiments you will also need two flashlights including fresh "D" size batteries.

WHAT IS ELECTRICITY?

To understand how electricity is produced, various theories have been offered by scientists. Today, the accepted theory is the atomic theory that assumes all matter is composed of atoms, tiny particles containing positive and negative electrical charges. The atom consists of a nucleus containing protons that are positively charged and, except for the hydrogen atom, neutrons that have no electrical

charge, and negatively charged electrons surrounding the nucleus. The atoms contain an equal number of protons and electrons. The number of protons differs in the various elements and determine their characteristics.

The positive electrical charge of the proton exactly balances the negative charge of the electron. Therefore, an atom in its normal state is electrically neutral. The positive charge is indicated by (+) and the negative charge by (—).

This is a very simplified and brief summary of atomic structure, but sufficient for our purposes here.

The electrons orbit around the nucleus at high speed, held to their paths by the attractive force of the positively charged protons which remain in the nucleus. The attraction between the protons and electrons decreases with distance, and the electron in the orbit furthest from the nucleus is held to the atom with so little force, it can wander away, moving at random from atom to atom. Such electrons that travel about are called free electrons. These are the electrons that are the basis of electricity.

Experiment 1. Empty the plastic bag in your unit. Cut a one-half inch strip from across the top of the bag and roll the rest

around the end of a wooden pencil, leaving at least an inch at the eraser end uncovered. Secure the plastic bag to the pencil with a bit of Scotch tape. You now have a "plastic rod."

Tie a piece of sewing thread to one end of the plastic strip and suspend it from a projection where it can hang freely away from the draft. Slide the plastic strip between your fingers several times. Holding the uncovered part of the pencil rub your plastic rod vigorously with your hand. Bring the plastic rod close to the suspended plastic strip. What happens? Does it move away from the rod?

Experiment 2. Now bring your hand close to the plastic strip. Does it move toward your hand and cling to it?

When you rubbed the plastic rod against the palm of your hand, some of the free electrons from your hand were transferred to the rod. The plastic rod, on acquiring an excess of electrons, became negatively charged and your hand on losing electrons, became positively charged. The same thing occurred when you rubbed the plastic strip between your fingers. Both were electrified by friction.

Many experiments similar to the one above have been performed by scientists, leading to the conclusion that like charges

repel and unlike charges attract.

Electricity produced by friction is known as static electricity, since the electrons accumulate on the surface and remain on the charged material, at least for a while.

Experiment 3. Place the heavier steel wire across the top of a jar or glass. Electrify the plastic strip and rod again with your hand as before. Allow the strip to hang about one-half inch from the end of the wire. Touch the rod to the other end of the wire (Fig. 1). What happens? Is the strip repelled?

Your results indicate that the electrons from the plastic rod must have moved onto the wire and traveled along its length giving it a negative charge.

Whenever an object shares an excess of electrons with a conductor, the electrons tend to distribute themselves evenly over the entire length of the conductor.

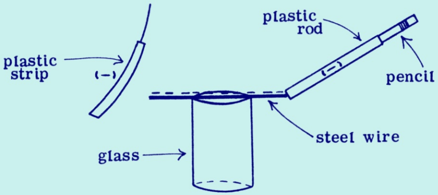

Fig. 1

In moving along the wire the free electrons produce an electric current.

The same is true if there is a deficiency of electrons. The deficiency is spread equally throughout the length of the wire.

Experiment 4. Electrify the plastic strip again and bring it close to the wire as before. Now touch the opposite end of the wire with your fingers. Is the plastic attracted to the wire?

When your positively charged fingers touch the end of the wire, free electrons from the atoms at the end of the wire move onto your fingers, leaving these atoms deficient in electrons and positively charged. The positively charged atoms now attract the free electrons in the atoms on the other side, away from your fingers. These atoms, in turn, becoming deficient in electrons, attract free electrons from their neighbors. The electrons travel progressively toward your fingers, until the end of the wire near the plastic strip finally becomes positively charged, attracting the negatively charged strip toward it.

This successive movement of electrons is called electron drift and is in essence what happens when an electric current travels along a wire.

Experiment 5. Remove the wire and replace it with a strip of paper ⅛-inch

wide cut from the card in your unit. Repeat the experiment. What happenes? Is the strip repelled? You will find that it is not affected by touching the plastic rod to the opposite end of the paper.

An electric current will pass more readily through some materials than others. A substance that allows a current to flow through it, as the steel wire did, is known as a conductor. Metals contain the most free electrons and so make the best conductors. Some, however, are better conductors than others. For example, copper is one of the best conductors and is used for electric wiring, while lead is a poor conductor. Some materials do not conduct electric currents and are known as insulators or nonconductors. Dry wood, most plastics, pure water, glass and rubber are examples of insulators. However, since there are a few free electrons in all materials, no substance is an absolute nonconductor.

Experiment 6. Electrify both plastics again. Gradually bring the rod toward the plastic strip. Note that it is repelled by the rod when it comes within a half inch or so of it. This is because a field of force exists around a charged body, called an electrostatic or electric field. A force is exerted on any charged body that

enters an electric field. If it is oppositely charged it is attracted and if it has a like charge it is repelled.

ELECTROMOTIVE FORCE

If a greater number of electrons are present at one end of a wire than at the other, a potential difference exists between the two. An electrical pressure is set up that pushes the free electrons toward the end with fewer electrons. This force that causes electrons to move toward the area deficient in electrons is called the electromotive force or voltage. For an electric current to flow, the electrons must move and in order for them to move there must be a difference in potential.

The main purpose of batteries and generators that supply our electricity is to create and maintain a potential difference to provide a constant flow of current.

By convention, an electric current is said to flow in the direction a positive charge would move, i.e., toward the negative charge. However, the actual flow of electrons, as in metallic conductors, we now know, is in the opposite direction—the negative charges move toward the positive. In the experiments in this unit, therefore, we shall always consider the current as flowing in the direction taken by the electrons.

CHEMICAL ACTION

Electricity may be produced by several means—friction, mechanical action, chemical action, heat, light, pressure and nuclear energy.

Mechanical action and chemical action are the most common means of producing electric energy. Mechanical action is used to supply the electricity in our homes and chemical action produces the electricity from cells and batteries.

There are two kinds of electric current—direct current (dc) and alternating current (ac). A direct current always flows in the same direction. This is the kind of current supplied by electric cells and batteries.

The electricity supplied by generators for our homes is alternating current. An alternating current flows in one direction and then in the other, changing direction continuously many times a second.

In order to produce an electric current, the object is to separate the negative and positive charges and make use of the electromotive force (emf) between them. Emf is measured in volts, and the greater the force the higher the voltage.

Since you will use dry cells from a flashlight as your source of electricity in the experiments in this unit, let us investigate

how electrical energy is obtained by chemical action.

DO NOT USE HOUSEHOLD CURRENT FOR ANY OF THE EXPERIMENTS IN THIS UNIT.

Many substances when dissolved in water, separate into their negatively and positively charged components, called ions. This is referred to as ionization or dissociation. For example, table salt or sodium chloride ($NaCl$) on dissolving in water dissociates into positively charged sodium ions, Na^+, and negatively charged chloride ions, Cl^-.

A substance that ionizes will conduct electricity and is called an electrolyte. Many salts, acids and bases are electrolytes. Some substances, like sugar, do not ionize when dissolved in water and are nonelectrolytes or nonconductors.

Experiment 7. Pour vinegar (acetic acid) to about one-half inch depth in a small glass or custard cup (glass) and add an equal amount of water, and stir the solution.

Cut a 1½-inch piece from your copper wire and a similar length from your zinc ribbon. Turn down one end of each metal about ¼-inch to form a hook.

Turn back about ¼-inch of the wire at each end of one of your 6½-inch long insulated wire. Hook the copper and zinc pieces to the ends of the insulated wire. Close the ends to hold them securely. Place the metal strips in the diluted vinegar. Do not immerse the ends of the insulated wire (Fig. 2).

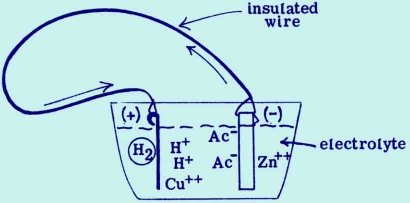

Fig. 2

After several minutes, examine the two metals. What do you see? Do you see tiny bubbles along the copper wire?

Acetic acid in solution ionizes into positive hydrogen ions (H^+) and negative acetate ions (CH_3COO^-, which may be abbreviated to Ac^-).

Zinc is a more active metal than copper and goes into solution more readily. When a zinc atom goes into solution it leaves two electrons behind and becomes positively charged. The zinc strip with two extra electrons, becomes negatively

charged. The zinc ions (Zn^{++}) repel any hydrogen (H^{+}) ions nearby. The repelled hydrogen ions eventually come in contact with the copper. When this happens, each hydrogen ion takes on an electron from the copper wire causing the wire to become positively charged. Two hydrogen atoms combine to form hydrogen gas (H_2) seen as bubbles on the copper wire. The acetate ions (Ac^{-}) may combine with either the copper or zinc ions to form copper acetate and zinc acetate. Some of the copper ions are repelled by the zinc ions and return to the copper wire, pick up electrons and return to their solid state.

As a result of these actions, an excess of electrons occurs at the zinc terminal and a deficiency at the copper end and an electromotive force is set up due to the potential difference. A flow of the excess electrons from the zinc to the copper terminal occurs along the insulated wire. These electrons are taken up by hydrogen ions and some of the copper ions. The zinc continues to go into solution, replacing the loss and at the same time pushing hydrogen and copper ions toward the copper terminal. The flow of electrons will continue until the zinc is all used up or the circuit is broken.

You have constructed in this experiment,

the simplest form of electrochemical cell, called a primary cell. The copper and zinc are the electrodes, connected by an external conductor (the insulated wire), and the acetic acid is the electrolyte.

You can form a primary cell in a similar way using almost any two different metals, and a suitable electrolyte. Some metals ionize more readily than others and in making an electrochemical cell, the metals are chosen according to their relative activities.

The elements have been arranged in a table according to their tendency to ionize. This is known as the electromotive series. The most active are at the top of the list and the less active below, and each metal is negative with respect to those listed beneath it. The further apart the metals are, the greater will be the electromotive force or voltage obtained.

zinc
iron
tin
lead
copper
silver
platinum
carbon

Note the relative positions of zinc and copper.

Experiment 8. Make another electrochemical cell using a 1½-inch length of the heavier steel wire in your unit as the negative electrode instead of the zinc. You can use the same piece of copper wire as the positive electrode.

In a glass container, dissolve one-half teaspoonful of table salt (sodium chloride, NaCl) in about one-half cup of water. The solution should be about one-inch deep. Use the same 6½-inch long insulated wire for the conductor. Iron as you can see from the electromotive series is more active than copper, so you know that the steel will be negative and the copper will be positive. After a few hours examine the cell. Is there a rusty deposit on the wire?

Iron ions react with water to form iron oxide (rust) when it goes into solution. Although a current is generated by this cell, you can see that this combination of materials would not be the best for making a practical electrochemical cell.

The dry cell used for flashlights and other devices is a primary cell also. The materials used to create the desired electric current have been carefully chosen after much experimentation to offer the most voltage with the greatest efficiency.

In a dry cell, the positive electrode is a

carbon rod. Carbon does not ionize. The negative electrode is zinc, shaped into a can to hold the electrolyte, a solution of zinc chloride and ammonium chloride in water with manganese dioxide added to prevent bubbles from accumulating on the carbon rod.

A dry cell is not really dry. It is called a dry cell because the electrolyte has been made into a paste so that it cannot spill. Electrochemical cells like those used in automobiles in which the solution is in liquid form are wet cells.

The potential difference of a particular type of dry cell is always the same, whether large or small. The size of a cell does not affect its electromotive force and therefore, its voltage, since the potential difference is determined by the chemical reaction resulting from the composition of the electrodes and the nature of the electrolyte. If you examine the wrapper on dry cells of different sizes, you will find that they are all marked 1.5 volts. Making a cell larger, however, will increase the amount of current it can deliver because there are more ions present to do the work.

Although single cells are often called batteries, technically a battery consists of two or more cells.

If you wish to obtain more power, you may connect several cells together in series and form a battery. When cells are arranged in series, the voltage of each cell is added to that of the others. With three cells, you would have a battery of 3 x 1.5 volts or 4.5 volts (Fig. 3).

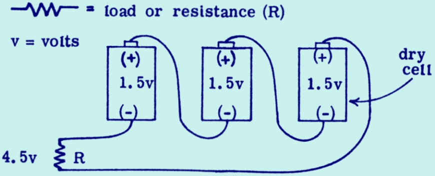

Fig. 3

Batteries may also be formed by connecting the cells in parallel (Fig. 4).

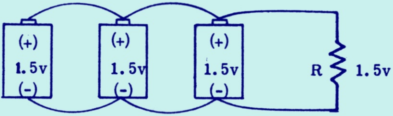

Fig. 4

In a parallel connection, all the negative terminals are connected together and all the positive terminals are joined. The emf of this battery is the same as that of a single cell and, therefore, is equal to 1.5 volts. In such a battery, the amount

of current drawn from each cell is ⅓ of that which would be drawn from a single cell.

Therefore, if you wish a battery to deliver a large current, the cells would be connected in parallel. If you want a greater voltage, they should be connected in series. To increase both, you would combine the two arrangements and form a series-parallel battery. Can you draw a diagram of such a battery?

In an electrochemical cell, both the positive and negative changes, carried by the ions, move within the electrolyte, but only the negative charges, electrons, travel along the metal external conductor.

ELECTROLYSIS

An electric current can produce three main effects: chemical, magnetic and heating effects.

Let us first observe the chemical effect.

Experiment 9. Cut the remaining piece of copper wire into two 1½-inch lengths for electrodes and attach each to one end of a 6½-inch length of insulated wire. Make a dilute solution of vinegar as before.

Connect the free ends of the two insulated wires to the opposite terminals

of a dry cell. Place the copper electrodes into the electrolyte. What happens? In a few minutes you will see bubbles forming on one of the copper wires. Which one?

As you know, acetic acid is composed of H^+ and Ac^- ions. When an electric current is passed through an electrolyte, an electric field is created causing electrons to flow into the electrolyte from the negative electrode (cathode) and exit from the positive electrode (anode). The positive hydrogen ions move toward the cathode and each ion picks up an electron. Two hydrogen atoms combine to form hydrogen gas (H_2), forming the tiny bubbles you see on the negative electrode. The acetate ions migrate to the positive electrode where they give up electrons. A stream of electrons flows through the wires, while in the electrolyte, the positive and negative ions move in opposite directions. Thus, electrical energy from the cell separates the negative and positive ions.

This separation of chemicals by means of an electric current is called electrolysis and the cells in which they take place are known as electrolytic cells (Fig. 5).

In the primary cell, chemical energy is converted into electrical energy as you have observed. In an electrolytic cell, the opposite happens. Electrical energy is

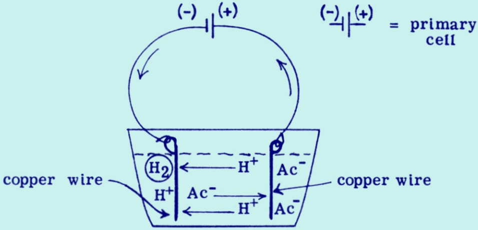

Fig. 5

transformed into chemical energy.

Electrolysis has wide applications. Pure metals are obtained from metal salts by electrolysis. Magnesium, for example, is separated from magnesium chloride in this way and aluminum is obtained from its ore, bauxite, by electrolysis.

Another application is electroplating. If we wish to put a coat of copper on a piece of iron, a salt solution of copper, such as copper sulfate, is used as the electrolyte and a direct current is passed through the solution. The copper ions are attracted to the negative iron electrode and adhere to the iron when they take on electrons and assume their solid state.

ELECTRIC CIRCUITS

Batteries and generators, producers of electricity, are useful to us only inasmuch as they can work for us. In order to do

work, the electrical system must be a closed one, so that there can be a continuous movement of electrons along a given path.

Electric circuits, from the simplest to the most complicated are designed to operate some device that we can utilize.

Experiment 10. Take one of your "D" size dry cells, the two ten-inch pieces of insulated wire and one flashlight lamp. Connect them into the circuit as shown in Fig. 6.

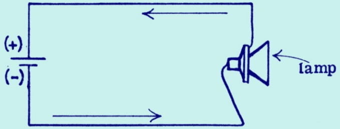

Fig. 6

Tape the wires to the dry cell terminals using non-conductive tape such as Scotch tape. To connect the flashlight lamp, be sure one wire touches the copper strip at the base of the lamp and the other the metal protector. If all your connections are properly made, the lamp will flash on.

This is the simplest form of circuit. The work it does is to light up the lamp. Any device a circuit operates is referred to as the load or resistance.

The generator in an electric circuit maintains the electromotive force necessary to move a current of electricity through the wires to operate a device. The emf is measured in volts and is usually 110 to 120 volts ac in household current.

Experiment 11. Your flashlight operates as a simple circuit. Look inside the flashlight holder and note the various connections. Can you outline the path the electrons take in order to light the lamp?

Experiment 12. A circuit may be in series or parallel, or a combination of the two.

Connect your second flashlight lamp to your simple circuit. Take one of the four-inch long pieces of insulated wire to connect them (Fig. 7).

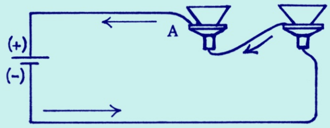

Fig. 7

You now have two lamps connected so that the current must pass through both in succession to complete the circuit. This is known as a series circuit. In a series circuit, the same amount of current flows

through each load along its path. If you wish add another lamp.

Experiment 13. Disconnect the wire at point A (Fig. 7). Do both lamps go out? Reconnect the wires and then unscrew one lamp. Do both go out? Rescrew this lamp and then unscrew the second lamp. What happens? Why?

In a series if you should break the circuit anywhere along its path both lamps will go out. Some types of Christmas tree lights are made in this manner. If one bulb is defective, the whole string of lights will go out. How would you locate the guilty bulb?

Experiment 14. Remove the lamps. Disconnect the cells from the wires. Then, midway along the two 10-inch wires, remove about one-half inch of the insulation to expose the bare wire.

Attach the wires to a cell again. (For a stronger current connect two or three cells in series using the 3-inch insulated wires.) Use the two four-inch pieces and attach one end of each to the bare space in the wires. Connect the free ends of the wires to the lamp. Does the lamp go on?

Connect a lamp between the ends of the 10-inch wires (Fig. 8).

Does the second lamp go on too? Do

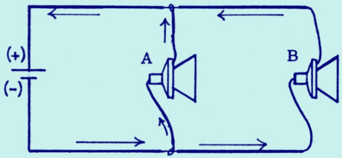

Fig. 8

both stay on? Is the brightness of the lights affected?

An arrangement such as this is called a parallel circuit. In a parallel circuit, the total current from and to the generator is divided. One part flows through the first lamp and the other through the second. The total current is the sum of the divided currents.

Break the circuit at A. Does the second lamp go out also? Disconnect the wire at B. Does the first lamp stay on?

In a parallel series, each load is independent of the other.

Household circuits are parallel. Why?

Experiment 15. A circuit may also be a combination of series and parallel connections. Can you devise circuits consisting of two series circuits connected in parallel? Two parallel circuits connected in series?

Experiment 16. Remove the first lamp. Then touch the exposed parts of the two

wires leading from the dry cell together. What happens to the other lamp? Does it go out?

By touching the wires together you created a short circuit. An electric current takes the path of least resistance so it did not light the lamp.

Short circuits are fire hazards because wires can become very hot and start a fire.

Experiment 17. For this experiment, if your flashlight is in a plastic case, you may use the top section, the part enclosing the lamp; otherwise use a small glass jar with a diameter of 1½ inches or so.

Attach one of the 10-inch wires leading from the cell to the top section of the flashlight or to the glass jar with strong tape

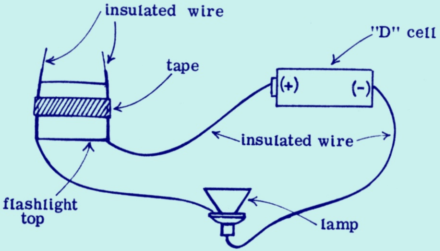

Fig. 9

(Fig. 9). Extend about one inch of the wire upright above the top edge. Opposite this wire tape the end of the 6½-inch wire in the same way (Fig. 9).

Connect a lamp between the 6½-inch wire and the other 10-inch wire leading from the dry cell.

Cut a strip from your aluminum foil, about ¼-inch wide and 1½-inch long, and a piece from your stiff paper about ½-inch wide and 1½ inches long. Mount the aluminum foil on the paper as shown in Fig. 10a.

Make a tiny hole in the foil with a needle and insert it through one end of one of the upright wires. Make a loop in the bare end of the other insulated wire, and bend it horizontally, to provide a flat surface on which the other end of the aluminum foil can rest. You now have a switch to open and close the circuit. To see whether your circuit is properly connected, check the lamp. It should go on each time the switch is closed (Fig. 10b).

A switch is merely a conductor placed between wires leading to the generator.

Experiment 18. Remove the switch and make a flat loop on the end of this wire also so that you will have two flat loops in which you can insert or place materials. Check various materials, such

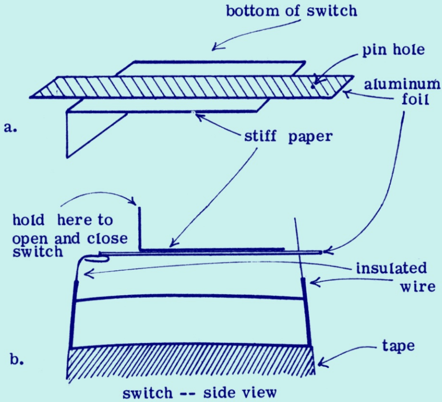

Fig. 10

as your piece of zinc, piece of plastic, your stiff paper, toothpick, needle and paper clip, to see if they are conductors.

Experiment 19. Place switches in various places in your circuits.

Experiment 20. How would you arrange a circuit so that the same light may be turned on at the bottom of a stairway and at the top?

In the experiments that follow, you will obtain better results if you use two or three cells in series.

HEATING EFFECT

When a current of electricity flows through a conductor, it meets with opposition somewhat like mechanical friction. This effect is known as resistance. Resistance causes some of the electrical current to be converted into heat energy. Some conductors resist the flow of electricity more than others and finer wires more than those of larger diameter of the same material.

Experiment 21. Bend the ends of your fine steel wire about one-fourth inch from the edge. Spread the looped wires apart. Insert the ends of the fine wire into the loops to close the circuit. After you have allowed the current to pass through the wire for several minutes, feel it cautiously. You will find that it has become quite hot.

Place a piece of heavier steel or the nail in your unit across the wires. Does it become warm? You will find that it does not heat up noticeably.

This thermal effect of electricity is very useful to us. Examine the flashlight bulb and you will see the fine wires inside which turn white hot because of resistance when a current is passed through them to provide light. Feel the bulb. Is it warm? Our electric stoves, heaters, toasters and

similar appliances depend upon the heating effect of electricity.

Experiment 22. Fuses in our electric wiring system protect the house wiring from becoming overheated by making use of electrical resistance. Just beneath the window in a fuse is a piece of metal with a comparatively low melting point that melts and breaks the circuit before the house wires can be heated if there is a sudden upsurge of current or a short circuit. Examine a fuse.

Can you construct one? Obtain some of the thinnest aluminum foil possible and cut a strip as shown in Figure 11. Secure it across the wires used for your switch. Be sure the circuit is closed. Allow the current to pass through it until the metal breaks apart. The point at the center should be as narrow as possible to obtain results since your battery does not deliver a great deal of current.

Experiment 23. Think of other devices and appliances that make use of the heating effects of electricity.

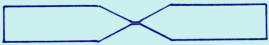

Fig. 11

MAGNETIC EFFECT

Experiment. 24. Replace your switch and check its operation.

Make a holder for your compass. Cut a ½ x 3-inch strip from your stiff paper. Fold it in two and tape it together. Paste or tape the compass to one end of the paper. Do not use permanent adhesive. If you wish to use tape, cut a piece of Scotch tape about one-half inch long and roll it into a cylinder with the sticky side out. Place the piece between the compass and the paper and press the compass down.

Hold the compass close to one of the wires leading from the battery. Close the switch. Does the compass move slightly?

As a current flows through a wire, a magnetic field is built around it.

A simple way of determining the direction of the magnetic field is the left-hand rule. Hold the wire with the left hand curling your fingers about it, with the thump pointing in the direction of the flow of electrons. Your fingers circle the wire in the direction of the magnetic lines of force and your thumb will point in the direction of the north pole of this magnetic field.

Experiment 25. Take your 6½-inch long wire and coil it around the nail in your unit about 8 or 9 times leaving about

one inch of wire free on each end. Remove the nail. The left-hand rule can be used to determine the north and south poles of the coil also.

Connect the coil to the wires that were used for the switch. Attach the switch between the coil and the lamp by making the proper connections. Bring your compass to one end of the coil and then close the switch. Does the needle move toward the coil? Which point of the compass is attracted? Place the compass at the opposite end of the coil. What happens? Break the circuit. What are your results? The movement of the compass needle may be very slight.

When the wire is coiled, each loop adds its magnetic field and the total force of the field is increased. The coil forms a temporary magnet and when the current stops flowing, the magnetic field disappears and the compass is no longer attracted.

Experiment 26. Insert the nail back into the coil and repeat the experiment. Is the movement of the compass needle more pronounced? The coil of wire and iron nail form an electromagnet when an electric current is passed through the wire. When a core of iron or steel is placed within a coil of wire through which an

electric current is flowing, the magnetic lines of force are increased because the lines of force pass more readily through iron than through the air. Thus, many more lines of force are present along the coil and the attractive force of the magnet is very much greater.

The more coils in the wire, the greater the magnetic force. Why? Can you demonstrate this?

Electromagnets have a wide variety of uses, from the doorbell to large magnets for lifting heavy steel objects, and from telegraph circuits to transformers.

Experiment 27. Place the fine steel wire into the coil and allow the current to flow through the coil continuously for several minutes. Then open the switch and remove the wire. Bring it close to an iron object. Is it attracted to it? If the attraction is not pronounced, replace it in the coil and allow the current to flow through the coil again for a longer time.

An electric current can be used to magnetize objects permanently.

Needles and nails are quickly magnetized by this means. Tools such as screwdrivers may be magnetized in this fashion.

Experiment 28. After the wire has been magnetized, suspend it from a piece of very fine sewing thread (silk would

be best). Allow the current to flow through the coil again and bring the wire close to one end of the coil. Is it attracted? Repeat at the other end of the coil and note your results.

Experiment 29. Coil your 24-inch long wire around one of your flashlight batteries (D size) leaving about four inches of straight wire at each end. Remove the coil and tape it together as shown below to hold the wire in place (Fig. 12a).

Make a little platform with a ⅝ x 4-inch strip from the stiff paper in your unit

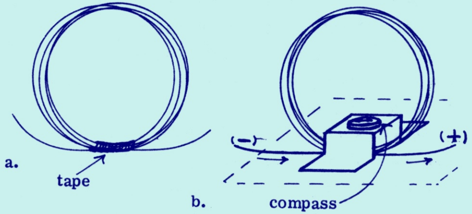

Fig. 12

for the compass which will be placed at the position shown in Fig. 12b. Secure the platform to a stiff surface such as cardboard after the compass has been placed in position within the coil.

Place the coil so that it is in line with the direction of the compass needle. Con-

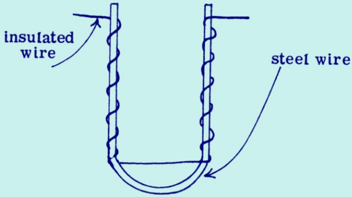

Fig. 13

nect one end of the wire to your battery, then touch the other end to the opposite terminal. Does the compass needle move? In which direction? Reverse the direction of the current and see what happens.

You have constructed a simple form of galvanometer, an instrument that detects an electric current.

Most of the electric meters in which the pointer moves across a dial along a circular path, such as the ammeter and voltmeter, are modifications of the galvanometer.

Experiment 30. Shape the remaining 3-inch length of heavier steel wire into a horseshoe. Take apart your galvanometer and use the wire for this experiment. Wind the insulated wire around the steel wire tightly, leaving about five inches of the insulated wire free at each end. Be sure to wind it in the direction shown in

Fig. 13, with the coils close together (not spread apart as in the diagram).

Allow a current to flow through the wire and pick up the fine steel wire or your nail with the magnet thus formed. Do you find that it is quite strong?

Check the poles in the magnet with your compass. What do you find?

In a horseshoe magnet, the north and south poles are close together and thus, its magnetic effect is concentrated in a smaller area, increasing its attractive force.

Open the switch. Does the nail drop away as soon as the flow of current ceases? This type of temporary magnet is used in an electric doorbell.

In these experiments you have shown that electricity can make things move.

ALTERNATING CURRENT

You have observed that an electric current produces a magnetic field.

The opposite is also true. A magnetic field can produce an electric current in a conductor that is a part of a circuit.

If a conducting wire is moved up and down across the lines of force of a strong

magnetic field, an electromotive force is set up causing a current to flow along the wire. The current flows in one direction when the conductor moves through the magnetic field upward and the opposite way when it is moved downward. As long as this up and down movement occurs across the field, a current will flow in one direction and then in the other, producing an alternating current.

The current will flow only when the conductor moves through the field.

This is called induced emf and is the basis of all the generators that produce the alternating current from magnetism to supply our homes with electric energy.

There are many books on electricity which take up the subject in detail. If you wish to study the subject further, most elementary physics books will be helpful.

Appreciation is expressed to Mr. Frank E. Jones, National Bureau of Standards, for reviewing this booklet.

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